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PHYTOEXTRACTION OF CADMIUM AND LEAD FROM CONTAMINATED SOIL BY *BRACHIARIA MUTICA* FORSK. (PARA GRASS)

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Abstract - A pot experiment was conducted to investigate the phytoextraction of cadmium (Cd) and lead (Pb) by *Brachiara mutica* Forsk. (para grass) in soil which was initially contaminated with 10, 100 and 300 mg/kg of metal. Plants were harvested after three months of planting and analyzed for cadmium and lead accumulation in aboveground shoots and roots. Soil was also analyzed for metal content before and after planting. Results show that the accumulation of both metals in the root was higher than in the aboveground shoot. The accumulation of both metals in all parts of the plant increases as the amount of metals applied to the soil increases. Cadmium was more strongly phytoextracted than lead.

INTRODUCTION

Industrialization has long been a parameter to indicate a country's development but along with it is the problem of increasing environmental pollution. Pollution is usually due to mining, manufacturing, vehicles and anthropogenic activity and when released to the environment will ultimately concentrate in soil and sediments (Prasad, 1997).

In the Philippines, mining industries are one of the major contributors to environmental pollution. Boac River in Marinduque was rendered biologically dead due to presence of highly poisonous mining wastes. The mining activities in Mt. Diwata and Mt. Diwalwal in Compostela Valley have contaminated the environment due to dangerous mining by-products (Carandang, 2003). These areas need immediate attention because they pose a major threat to people living near or within the area and their immediate environment.

Remediation of these areas then has to be implemented to prevent adverse effects on humans and environment. One of the methods that can be employed is "phytoremediation", a form of ecological engineering, which has emerged as an alternative to physicochemical methods and has proven to be effective and relatively inexpensive. This method uses plants to remove, destroy or sequester hazardous substances from the environment (Glick and Pattern, 2000). The utilization of plants to transport and concentrate metals from the soil into harvestable parts of roots and aboveground shoots is usually called "phytoextraction". Phytoextraction of metals from the environment can be a viable commercial activity (Alkorta and Garbisu, 2001).

Plants are used due to their remarkable ability to concentrate elements and compounds from the environment and to metabolize various molecules in their tissues (Alkorta and Garbisu, 2001). Plants also rehabilitate metal-contaminated sites because it improves the soil condition and favors the growth of beneficial organisms (Carandang, 2003). This method of using plants is also cost-effective and aesthetically pleasing technology.

Several plants have already been identified as metal-hyperaccumulator species but most have low growth rates which decrease their efficiency as phytoextractors (Beau-Grasset, 2000). To address this limitation, recent studies have focused on plants, such as grasses, which can bioaccumulate heavy metals and have high biomass production.

Several studies on a vetiver grasses in Thailand have shown that it can tolerate and

Figure 1. *B. mutica* Forsk. (para grass).

accumulate high amounts of heavy metals in contaminated soil (Chantachon, *et al.*, 2002).

This study aims to evaluate the phytoextraction of cadmium and lead in contaminated soils by *Brachiaria mutica* Forsk. (para grass) (Figure 1). Para grass is a perennial and robust grass with well-developed roots. It is widely distributed throughout the tropics and is common in the Philippines. It can be found extensively in Mindanao and is widely grown in Davao Province (Country Pasture /Forage Resources Profiles, 2002). It is commonly used as green fodder, hay, or as pasture grass in rotational grazing. Para grass grows well in warm and humid climate and grows more vigorously in moist places (Hernandez, 1980).

The phytoextraction of cadmium (Cd) and lead (Pb) by para grass in soil which was initially contaminated with 10, 100 and 300 mg/kg of metal was investigated. Plants were harvested after three months of planting and analyzed for metal content in aboveground shoots and roots. The soil was also collected and analyzed for Cd and Pb content.

MATERIALS AND METHODS

Plant Material

Samples of *B. mutica* Forsk (para grass) were obtained from a vacant lot in Davao City. These were cleaned and the stems were cut into 30 cm strips containing 3 nodes each. Stem cuttings were analyzed for background Cd and Pb. A pressed specimen was identified by Ms Fe Bagajo of the Biology Department, Ateneo de Davao University.

Soil

Sacks of soil were mixed thoroughly to achieve homogeneity, spread out on trays, air-dried and allowed to pass through a 3.125 mesh sieve to remove all materials greater than 9.5 mm. The soil was then treated with cadmium nitrate and lead nitrate solutions separately to obtain soil concentrations of 10, 100 and 300 ppm Cd and Pb.

Soil (10.0 kg) was weighed and placed in a transparent cellophane bag. A 3.0 L solution of 33.3 ppm Cd as $Cd(NO_3)_2$ was added to the soil and mixed to homogeneity. The treated soil was then air-dried for four weeks to obtain a Cd concentration of 100 mg Cd/10.0 kg soil or 10 ppm Cd in soil. For 100 and 300 ppm Cd soil concentration, 333.3 and 1000 ppm Cd solutions were used respectively. For soils treated with lead solutions of $Pb(NO_3)_2$ were used. Prior to planting, soil samples were analyzed to determine the initial concentration of cadmium and lead present in soil.

There were three replicates for each treatment which were planted with para grass. A control run (treated soil, no para grass) and a blank run (untreated soil, no para grass) were included.

Planting

Para grass was planted by placing one stem cutting in the 2 kg treated soil leaving about 20 cm of the stem above the soil surface. Each pot was watered everyday with 250 mL tap water. This amount was enough to moisten the soil without draining from the bottom of the pot. The pots were enclosed with a garden net and a laminated sack as overhead cover.

Sampling Method

The aboveground shoot and roots were harvested after three months of planting, dried in an oven at 60 °C for three days and then shredded separately. Soil samples were also air-dried and passed through a 20 mesh sieve. Homogenized samples were placed in a plastic cellophane and stored in a desiccator.

Sample preparation and analysis

One gram of ground dried plant sample or sieved dried soil was weighed and placed in a 125 mL Erlenmeyer flask. Ten mL of aqua regia (3 HCl: 1 HNO_3) were added and the sample was heated gently on a sand bath under a hood. Heating was continued until the solution became yellowish in color. The volume of solution was kept to a minimum without allowing the solution to dry out. The solution was cooled, filtered through two sheets of Whatman #42 filter paper and quantitatively transferred to a 50- mL volumetric flask with distilled water. The filtrate was saved for AAS analysis.

The control and blank samples from each run were also prepared for AAS analysis. Spiked samples were prepared to check the percent recovery.

The samples were analyzed together with the blank, spike samples and cadmium and lead standards using an Atomic Absorption Spectrophotometer (Perkin Elmer Analyst 100) at wavelengths of 228.8 and 283.3 nm respectively.

Cadmium and lead accumulation in each part of the plant was calculated and expressed as mg Cd or Pb per kg of dry weight sample.

The metal was reported as phytoextraction coefficient, that is, the ratio of metal concentration in the plant roots or aboveground shoots to the initial soil concentration of the metal (Schnoor, 1997).

The percent efficiency removal was also calculated by comparing the total cadmium or lead accumulation in plant with the total amount of metal initially present in the experimental pot.

RESULTS AND DISCUSSION

The grass in all of the runs had 100% survival showing that para grass can tolerate both Cd and Pb concentrations in soil to as high as 300 mg metal/kg soil.

The results also showed an accumulation of both heavy metals in all parts of the plant such as the aboveground shoots and roots with the latter having a higher accumulation (Table 1). The 300 mg metal/kg soil showed the highest accumulation of metal in both plant parts. In the shoots, Cd and Pb accumulations were 0.971 and 1.341 mg metal/kg dry weight, respectively, whereas in roots, the accumulations were 10.7 and 5.80 mg metal/kg dry weight, respectively.

The concentration of heavy metals phytoextracted increased as the amount of metal applied to the soil increased (Figure 2 and 3). However, there was more Cd accumulated than Pb in both plant parts; this may be due to the fact that Pb is held strongly by organic matter and minerals present in soil making it is less available to the plant (McBride, 1994).

Table 1. Metal accumulation in aboveground shoots and roots of *B.mutica* Forsk.

Plant part	metal concentration in soil *(mg metal/kg soil)*	total mean metal concentration *(mg Cd/kg dry weight)*	*(mg Pb/kg dry weight)*
shoots	10	0.267±0.035	0.172±0.044
	100	0.322±0.051	0.566±0.050
	300	0.971±0.057	0.705±0.047
roots	10	1.9±0.2	1.341±0.097
	100	6.46±0.45	2.33 ±0.15
	300	10.7±1.4	5.80±0.12

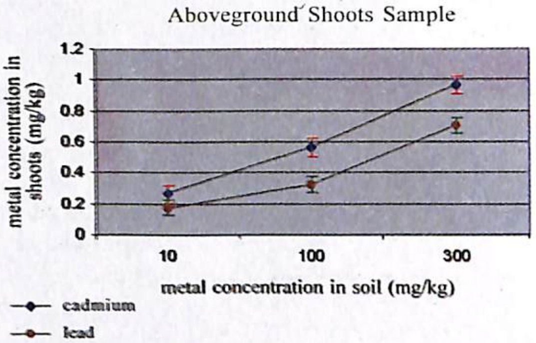


Figure 2. Cadmium and lead accumulation in aboveground ground shoot of *B. mutica* Forsk. (para grass)

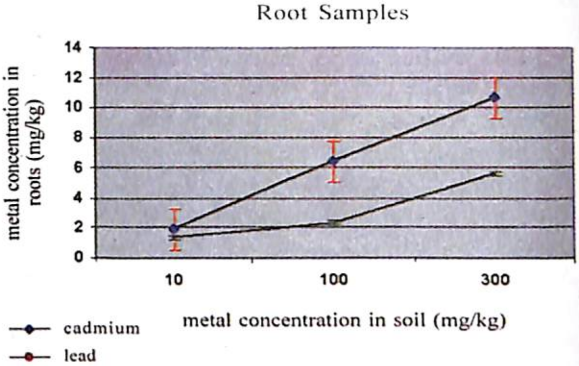
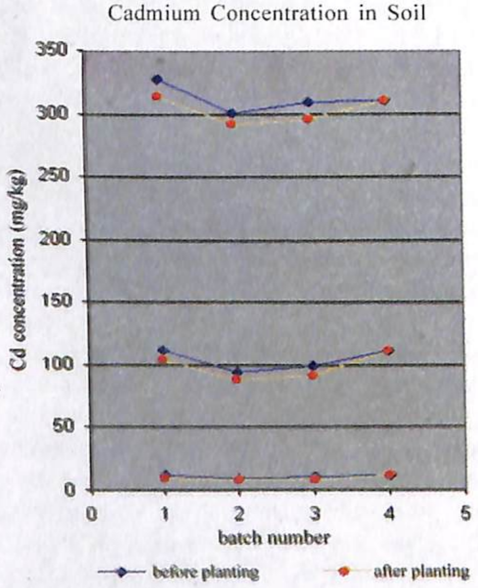


Figure 3. Cadmium and lead accumulation in roots of *B. mutica* Forsk. (para grass)

Table 2. Phytoextraction Coefficient of *B.mutica* Forsk.

Plant part	metal concentration in soil *(mg metal/kg soil)*	total mean metal concentration *Cadmium*	*Lead*
shoots	10	0.0239 ± 0.0038	0.0164 ± 0.0050
	100	0.00552 ± 0.0013	0.00366 ± 0.00058
	300	0.00311 ± 0.00022	0.00242 ± 0.00024
roots	10	0.173 ± 0.026	0.128 ± 0.023
	100	0.0630 ± 0.0069	0.0265 ± 0.0019
	300	0.0342 ± 0.0046	0.0199 ± 0.0015



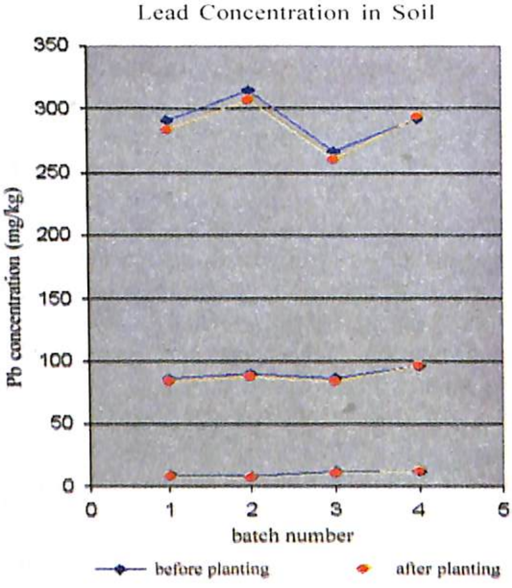


Figure 4. Metal concentration in soil before and after planting of para grass.

Table 3. Efficiency of metal removal by *B.mutica* Forsk.

metal concentration in soil	**% Efficiency Removal**	
(mg metal/kg soil)	***Cadmium***	***Lead***
10	0.0085	0.0077
100	0.0024	0.0017
300	0.0012	0.0011

The phytoextraction coefficient by para grass decreases as the concentration of metal in soil increases. The data showed that para grass was more efficient in extraction at lower metal concentrations in the soil. Table 2 shows that both the shoots and roots have a higher coefficient at 10 mg/kg of Cd and Pb concentration in soil. However, the roots have higher phytoextraction coefficients than the shoots.

To correlate the removal of both metals from soil, the soil was also analyzed for metal after planting para grass. Figure 4 showed no significant change of concentration in the control runs (soil samples with no grasses planted). Therefore the decrease of the metal concentration in soils can be attributed to the accumulation of the metal by the grass.

The highest efficiencies obtained for para grass were 0.0085% for cadmium and 0.0077% for lead at 10 mg metal/kg soil group (Table 3). These results are slightly lower than the criteria set for a plant to be designated as a hyperaccumulator plant which is 0.01% for cadmium and 0.1% for lead (Reeves and Baker, 2000). However, despite its lower metal accumulation efficiency, para grass may actually remove more total metal because of its greater biomass and water uptake rates (Negri, 1996).

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